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A SURVEY ON CLUSTERING TECHNIQUES FOR WIRELESS SENSOR NETWORK

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Abstract: *Wireless sensor networks have been used in various fields like battle feilds, surveillance, schools, colleges, etc. It has been used in our day-to-day life. Its growth increases day by day. Sensor node normally senses the physical event from the environment such as temperature, sound, vibration, pressure etc. Sensor nodes are connected with each other through wireless medium such as infrared or radio waves it depends on applications. Each node has its internal memory to store the information regarding the event packets. In this paper we will come to know the various algorithms in clustering techniques for wireless sensor networks and discuss them. Clustering is a key technique used to extend the lifetime of a sensor network by reducing energy consumption .It can also increase network scalability. Sensor nodes are considered to be homogeneous since the researches in the feild of WSNs have been evolved but in reality homogeneous sensor networks hardly exist. Here we will discuss some of the impact of heterogeneous sensor networks on WSN and various clustering algorithms used in HWSN.*

Keywords: *Base Station (BS), Cell Header (CH), inter-cluster communication, intra- cluster communication.*

I. INTRODUCTION

With the advances in the technology of micro electromechanical system (MEMS) and developments in wireless communications, wireless sensor networks have emerged [1]. In past few years, wireless sensor networks (WSNs) have become one of the most interesting areas of research. A WSN is composed of a number of wireless sensor nodes which form a sensor field and a sink. These large numbers of nodes with low-cost, low-power, and capable of communication at short distances perform limited computation and communicate wirelessly form the WSNs [2]. Specific functions such as sensing, tracking and alerting [3] can be obtained through cooperation among these nodes. These functions make wireless sensors very useful for monitoring natural phenomena, environmental changes [4], controlling security, estimating traffic flows, monitoring military application [5], and tracking friendly forces in the battlefields. These tasks require high reliability of the sensor networks. To make sensor networks more reliable, the attention to research on heterogeneous wireless sensor networks has been increasing in recent past [6-9].

In order to support data aggregation through efficient network organization, nodes can be partitioned into a number of small groups called *clusters*. Each cluster has a coordinator, referred to as a *cluster head*, and a number of *member* nodes. Clustering results in a two-tier hierarchy in which cluster heads (CHs) form the higher tier while member nodes form the lower tier. Figure 1 illustrates data flow in a clustered network. The member nodes report their data to the respective CHs. The CHs aggregate the data and send them to the central base through other CHs. Because CHs often transmit data over longer distances, they lose more energy compared to member nodes. The network may be reclustered periodically in order to select energy-abundant nodes to serve as CHs, thus distributing the load uniformly on all the nodes. Besides achieving energy efficiency, clustering reduces channel contention and packet collisions, resulting in better network throughput under high load. Clustering has been shown to improve *network lifetime*, a primary metric for evaluating the performance of a sensor network. Although there is no unified definition of "network lifetime," as this concept depends on the objective of an application, common definitions include the time until the first/last node in the network depletes its energy and the time until a node is disconnected from the base station.

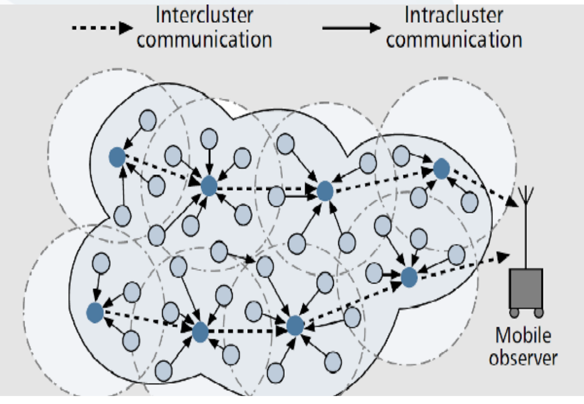

Figure 1. Illustration of data flow in a clustered network

The important components of wireless sensor network are discussed below:

- *Sensor Node:* A sensor node is the core component of a WSN. Sensor nodes can take on multiple roles in a network, such as simple sensing; data storage; routing; and data processing.
- *Clusters:* Clusters are the organizational unit for WSNs. The dense nature of these networks requires the need for them to be broken down into clusters to simplify tasks such a communication.
- *Clusterheads:* Clusterheads are the organization leader of a cluster. They often are required to organize activities in the cluster. These tasks include but are not limited to data-aggregation and organizating the communication schedule of a cluster.
- *Base Station:* The base station is at the upper level of the hierarchical WSN. It provides the communication link between the sensor network and the end-user.
- *End User:* The data in a sensor network can be used for a wide-range of applications. [1] Therefore, a particular application may make use of the network data over the internet, using a PDA, or even a desktop computer. In a queried sensor network (where the required data is gathered from a query sent through the network). This query is generated by the end user.

II. RELATED WORKS

Many researchers have proposed different techniques related to clustering in wireless sensor network. The LEACH protocol [2] is an application-specific clustering protocol, which has been shown to significantly improve the network lifetime. It assumes that every node is reachable in a single hop and that load distribution is uniform among all nodes. LEACH assigns a fixed probability to every node so as to elect itself as a CH. The clustering process involves only one iteration, after which a node decides whether to become a CH or not. Nodes take turns in carrying the role of a CH. However, the LEACH protocol is not heterogeneity-aware, in the sense that when there is an energy difference to some threshold between these nodes in the network, the sensors die out faster than a more uniform energy setting [2]. In real life situation it is difficult for the sensors to maintain their energy uniformly, this makes energy imbalance between nodes to occur easily. LEACH assumes that the energy usage of each node with respect to the overall energy of the system or network is homogeneous. Conventional protocols such as Minimum Transmission Energy (MTE) and Direct Transmission (DT) do not also assure a balanced and uniformly use of the sensor's respective energy as the network evolves. In Distributed Energy-Efficient Clustering algorithm (DEEC) [7], a probability based clustering algorithm was proposed. DEEC elects cluster heads based on the knowledge of the ratio between residual energy of each nodes and the average energy of the network. This knowledge however requires additional energy consumption to share the information among the sensor nodes. Stable Election Protocol (SEP) [8] is another heterogeneity-aware protocol. It does not require energy knowledge sharing but is based on assigning weighted election probabilities of each node to be elected cluster head according to their respective energy. This approach ensures that the cluster head election is randomly selected and distributed based on the fraction of energy of each node therefore assuring a uniform use of the nodes energy. In SEP, two types of nodes (two tier in-clustering) and two level hierarchies were considered. SEP is based on weighted election probabilities of each node to become cluster head according to the remaining energy in each node. A survey of clustering algorithm was presented in Ref. [9]; the even distribution of sensors in clusters is another primary objective of clustering called load balancing that needs to be considered when designing a robust protocol for WSNs [7]. The clustering issue was also discussed in a review on wireless multimedia sensor networks [1]. The contribution of this work is a SEP extension called SEP-E, by considering a three-tier node classification in a two-level hierarchical network. The HEED protocol considers multi-hop network and assumes that all nodes are equally important. A node who has the highest residual energy is considered as the cluster-head. In HEED, each nodes execute a constant number of iterations.

The new node type for the purpose of this study is referred to as "intermediate nodes", which serves as a bridge between the advanced nodes and the normal nodes. The intermediate nodes can take on the role of information fusion and filtering depending on the application settings, which we intend to study further. Our goal is to achieve a robust self-configured WSN that maximizes its lifetime.

III. OVERVIEW OF PROPOSED ALGORITHMS

A. Heuristic Algorithms

An heuristic algorithm is an algorithm that usually has one or both of the following goals in solving a problem:

- Finding an algorithm with reasonable run-time (time needed to set up clusters is affordable); and/or
- With finding the optimal solution. This means that a heuristic algorithm leads to reasonable performance and is not based on particular metrics.

There are many types of heuristic algorithms that exist in choosing cluster-heads. We will see each of these algorithms one by one.

Linked Cluster Algorithm (LCA) [4]:

LCA, was one of the very first clustering algorithms developed. It was initially developed for wired sensors, but later implemented in wireless sensor networks. In LCA, each node is assigned a unique ID number and has two ways of becoming a cluster-head. The first way is if the node has the highest ID number in the set including all neighbor nodes and the node itself. The second way, assuming none of its neighbors are clusterheads, then it becomes a clusterhead.

Linked Cluster Algorithm 2 (LCA2) [5]:

LCA2 was proposed to eliminate the election of an unnecessary number of clusterheads, as in LCA. In LCA2, they introduce the concept of a node being covered and non-covered. A node is considered covered if one of its neighbours is a cluster-head. Clusterheads are elected starting with the node having the lowest ID among non-covered neighbours.

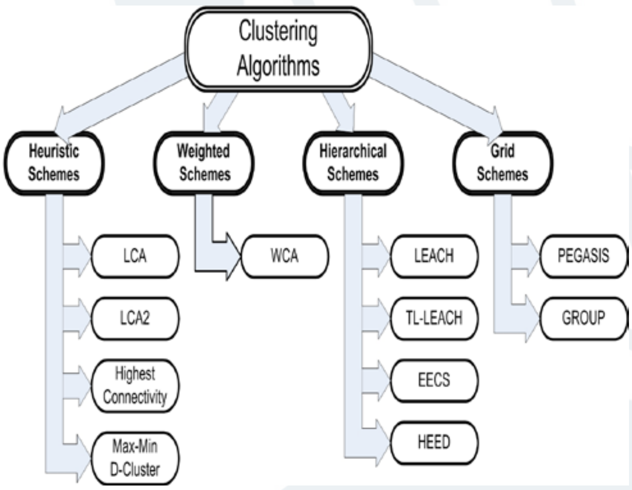

Figure 2: Classification of proposed clustering schemes

Highest-Connectivity Cluster Algorithm [6]:

This algorithm is similar to LCA. In this scheme the number of node neighbours is broadcast to the surrounding nodes. The result is that instead of looking at the ID number, the connectivity of a node is considered. The node with the highest connectivity (connected to the most number of nodes) is elected cluster-head, but in the case of a tie, the node with the lowest ID prevails.

Max-Min D-Cluster Algorithm:

With Max-Min D cluster, the authors[11] propose a new distributed cluster-head election procedure, where no node is more than d (d is a value selected for the heuristic) hops away from the cluster-head. This algorithm provides load balancing among cluster-heads. The cluster-head selection criteria is developed by having each node initiate 2d rounds of flooding, from which the results are logged. Then each node follows a simple set of rules to determine their respective cluster-head. The 1st d rounds are called flood-max, used to propagate the largest node ids. After this is complete, the 2nd d rounds of flooding occur. This round is called flood-min, used to allow the smaller node id to reclaim some of their territory. Then each node evaluates the logged entries following the rules listed below [1]:

• *Rule 1*: Each node checks to see if it has received its own id in the 2nd d rounds of flooding. If it has, then it can declare itself the cluster-head and skip the other rules. Otherwise it proceeds to Rule 2.

• *Rule 2*: Each node looks for node pairs. Once this is complete, it selects the minimum node pair to be the cluster-head. If a node pair does not exist, they proceed to Rule 3.

• *Rule 3*: Elects the maximum node id in the 1st d rounds of flooding as the cluster-head for this node.

This algorithm is valid only if the following two assumptions are made:

• *Assumption 1*: During the flooding, no node id will propagate further than d-hops from the originating node.

• *Assumption 2*: All nodes that survive the flood-max elect themselves cluster-heads.

B. Weighted Schemes

Weighted Clustering Algorithm (WCA) [6]:

The algorithm explained in this section is a non-periodic procedure to the cluster-head election, invoked on demand every time a reconfiguration of the networks topology is unavoidable.[6].This clustering algorithm tries to find a long-lasting architecture during the first cluster-head election. When a sensor loses the connection with any cluster-head, the election procedure is invoked to find a new clustering topology. This is an important feature in power saving, as the re-election procedure, which consumes energy, occurs less frequently. This algorithm is based on a combination of metrics that takes into account several system parameters such as: the ideal node degree; transmission power; mobility; and the remaining energy of the nodes. Depending on the specific application, any or all of these parameters can be used as a metric to elect cluster-heads. Another important aspect of the algorithm is that it is fully distributed; meaning that all the nodes in the mobile network share the same responsibility acting as cluster-heads.

Cluster-head election procedure:

The election procedure is based upon a global parameter , that is called combined weight, which is described by[6]:

$$W_v = w_1\Delta_v + w_2 D_v + w_3 M_v + w_4 P_v$$

Where, w1, w2, w3, w4 are the weighing factors for the corresponding system parameters. The weighting factors can be chosen based upon the specific application. The combined weight is calculated by each node and broadcast across the network. The node with smallest Wv is chosen as the cluster-head. The first component, w1Δv, helps in efficient MAC functionality, as it is always important to have a bound on the maximum number of nodes in a cluster. The second component, Dv, is the average distance from the neighbours and is strictly related to power consumption. It is known [6] that more power is required for long range transmission. The third component is due to mobility of the nodes. It is desirable that a cluster-head moves very slow, in order to have a more stable cluster architecture. From this point of view a node that moves slowly is always a better choice to be a cluster-head [6]. The last component is directly related to the available energy in a node: if a node was already a cluster-head it may have consumed a large amount of energy and should not be considered for the next cluster-head election. The weighing factors (w1,w2,w3,w4) can be chosen according to the system needs. For example, power control is very important in CDMA networks [6], thus the weight of the corresponding parameter. The flexibility of changing the weight factors helps in the application of this algorithm for different implementations.

Complexity due to distributiveness:

The time required for the selection of the node with minimum Wv depends on the implementation of the algorithm. As it is not possible [6] to have a centralized server in ad hoc sensor networks, the algorithm proposes a distributed solution in which all nodes broadcast their ids along with Wv values. Each node receives the broadcast from its neighbors and stores the information. The stored information is again exchanged with the immediate neighbors and the process continues until all the nodes become aware of the node with the smallest Wv. The time required will depend on the diameter of the underlying network.

C. Hierarchical Schemes

LEACH [5]:

Low-Energy Adaptive Clustering Hierarchy (or LEACH) was one of the first major improvements on conventional clustering approaches in wireless sensor networks. Conventional approaches algorithms such as MTE (Minimum-Transmission-Energy) or direct-transmission do not lead to even energy dissipation throughout a network. LEACH provides a balancing of energy usage by random rotation of clusterheads. The algorithm is also organized in such a manner that data-fusion can be used to reduce the amount of data transmission. The decision of whether a node elevates to clusterhead is made dynamically at each interval. The elevation decision is made solely by each node independent of other nodes to minimize overhead in clusterhead establishment. This decision is a function of the percentage of optimal clusterheads in a network (determined a priori on application), in combination with how often and the last time a given node has been a clusterhead in the past. The threshold function is defined as:

T(n) ={P/1−P(r mod 1/P), if n € G
Otherwise 0

where n is the given node, P is the a priori probability of a node being elected as a cluster-head, r is the current round number and G is the set of nodes that have not been elected as cluster-heads in the last 1/P rounds. Each node during cluster-head selection will generate a random number between 0 and 1. If the number is less than the threshold (T(n)), the node will become a cluster-head. Following elevation to cluster-head, the new cluster-head will broadcast its status to neighbouring nodes. These nodes will then determine the optimal cluster-head (in terms of minimum energy required for transmission) and relay their desire to be in that particular cluster. The broadcast messages as well as cluster establishment messages are transmitted using CSMA (Carrier Sense Multiple Access) to minimize collisions. Following cluster establishment, cluster-heads will create a transmission schedule and broadcast the schedule to all nodes in their respective cluster. The schedule consists of TDMA slots for each neighbouring node. This scheduling scheme allows for energy minimization as nodes can turn off their radio during all but their scheduled time-slot.

TL-LEACH [5]:

Two-Level Hierarchy LEACH (or TLLEACH) is a proposed extension to the LEACH algorithm. It utilizes two levels of cluster-heads (primary and secondary) in addition to the other simple sensing nodes. In this algorithm, the primary clusterhead in each cluster communicates with the secondaries, and the corresponding secondaries communicate with the nodes in their sub-cluster. Data-fusion can also be performed as in LEACH. In addition, communication within a cluster is still scheduled using TDMA time-slots. The organization of a round will consist of first selecting the primary and secondary clusterheads using the same mechanism as LEACH, with the a priori probability of being elevated to a primary cluster-head less than that of a secondary node. Communication of data from source node to sink is achieved in two steps :

1. Secondary nodes collect data from nodes in their respective clusters. Data-fusion can be performed at this level.
2. Primary nodes collect data from their respective secondary clusters. Data-fusion can also be

implemented at the primary cluster-head level. The two-level structure of TL-LEACH reduces the amount of nodes that need to transmit to the base station, effectively reducing the total energy usage.

EECS:

An Energy Efficient Clustering Scheme (or EECS) is a clustering algorithm in which cluster-head candidates compete for the ability to elevate to cluster-head for a given round. This competition involves candidates broadcasting their residual energy to neighbouring candidates. If a given node does not find a node with more residual energy, it becomes a cluster-head. Cluster formation is different than that of LEACH. LEACH forms clusters based on the minimum distance of nodes to their corresponding cluster-head . EECS extends this algorithm by dynamic sizing of clusters based on cluster distance from the base station[4] . The result is an algorithm that addresses the problem that clusters at a greater range from the base station require more energy for transmission than those that are closer. Ultimately, this improves the distribution of energy throughout the network, resulting in better resource usage and extended network lifetime.

HEED:

Hybrid Energy-Efficient Distributed Clustering (or HEED) is a multi-hop clustering algorithm for wireless sensor networks, with a focus on efficient clustering by proper selection of cluster-heads based on the physical distance between nodes. The main objectives of HEED are to:

- Distribute energy consumption to prolong network lifetime;
- Minimize energy during the cluster-head selection phase;
- Minimize the control overhead of the network.

Clusterheads are determined based on two important parameters:

1. The residual energy of each node is used to probabilistically choose the initial set of clusterheads. This parameter is commonly used in many other clustering schemes.
2. Intra-Cluster Communication Cost is used by nodes to determine the cluster to join.

IV. GRID SCHEMES

A. PEGASIS

Power-Efficient GAthering in Sensor Information Systems (or PEGASIS) is a data-gathering algorithm that establishes the concept that energy savings can result from nodes not directly forming clusters. The algorithm presents the idea that if nodes form a chain from source to sink, only 1 node in any given transmission time-frame will be transmitting to the base station. Data-fusion occurs at every node in the sensor network allowing for all relevant information to permeate across the network [5]. In addition, the average transmission range required by a node to relay information can be much less than in LEACH, resulting in an energy improvement versus the hierarchical clustering approach.

B. GROUP

The Group algorithm is a grid-based clustering algorithm. In this algorithm one of the sinks (called the primary sink), dynamically, and randomly builds the cluster grid . The cluster-heads are arranged in a grid-like manner as in Fig. 3. Forwarding of data queries from the sink to source node are propagated from the Grid Seed (GS) to its cluster-heads, and so on. The GS is a node within a given radius from the primary sink. In terms of cluster-head selection, on a given round the primary sink selects a GS based on residual energy. Once the GS has been selected, the GS selects cluster-heads along the corners of the grid at a range R. Each new cluster-head will then select more cluster-heads along the grid until all cluster-heads have been selected. These selections are based on the residual energy of nodes near the corners of the grid. Data transmission in GROUP is dependent on the type of data being collected. In the case of a location unaware data query (data that is not dependant on the location of the sensing node), the query is passed from the central most sink in the network to its nearest cluster-head. That cluster-head will then broadcast the message to neighbouring cluster-heads. If the data is location aware, then the requests are sent down the chain of cluster-heads towards the specified region using unicast packets. For both data queries, data is transmitted upstream through the chain of cluster-heads established during cluster formation. Energy conservation is achieved due to the lower transmission distance for upstream data. In LEACH, a cluster-head must transmit data to the base station directly, while in GROUP, the data is transmitted across short ranges through the upstream path[6].

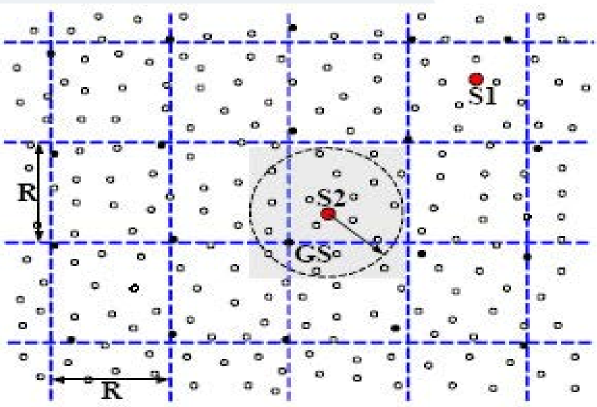

Figure 3: GROUP Example of Cluster Grid

V. CLUSTERING ALGORITHMS FOR HETEROGENEOUS WIRELESS NETWORK

A WSN is composed of hundreds of sensor networks distributed randomly. Clustering is one of the best technique to increase network heterogeneity. Heterogeneous network should be energy efficient to take the advantages of node heterogeneity. So now we will discuss some of the clustering prtocols for heterogeneous wireless sensor network[1].

A. Stability-oriented clustering protocols for HWSNs

Here we will discuss the stability period of wireless sensor network. Stability period is actually the time interval before the death of the first node. It is very important for the applications where the response from the response nodes must be reliable.

B. Stable Election Protocol for Clustered HWSNs

Smaragdakis G. *et al.* describe the impact of heterogeneity on the heterogeneous-oblivious protocols and instability of the protocols like LEACH, in the presence of heterogeneity, once some nodes die [2]. So he introduced a heterogeneity protocol named, Stable Election Protocol (SEP).It Ensures that the cluster-head is selected based the fraction of energy of each node, this assures each nodes energy is properly used. In SEP, two types of nodes (normal and advanced) are considered. It is based on weighted election probabilities of each node to become cluster head according to the remaining energy in each node. This prolongs the stability period i.e. the time interval before the death of the first node. Virtually, there are $n\cdot(1+\alpha\cdot m)$ nodes with energy equal to the initial energy of a normal node. In the heterogeneous scenario, the average number of cluster heads per round per epoch is equal to $n\cdot(1 + \alpha\cdot m)\cdot Pnrm$. The weighed probabilities for normal and advanced nodes are respectively:

$$Pnrm = Popt / (1+\alpha m)\ ,\ Padv = Popt\ (1+\alpha)/(1+\alpha m)$$

In most rounds, no cluster head is selected by SEP. In such rounds where no CH is selected, the data packets cannot be transmitted to the base station. This is a great disadvantage to the reliable transmission in the networks, especially for some important real-time transmission tasks.

C. Novel Stable Selection and Reliable Transmission Protocol for Clustered HWSN

H. Zhou *et al* propose a model of energy and computation heterogeneity for heterogeneous wireless sensor networks[3]. They also propose a protocol named Energy Dissipation Forecast and Clustering Management (EDFCM) for HWSNs. This algorithm balances the energy consumption round by round, which will provide the longest stability period for network. The heterogeneous model they consider is composed of three types of nodes including Type_0, Type_1 and some management nodes as shown in Fig. 1. Type_0 and Type_1 nodes vary in capabilities of sensing, energy and software. They have the responsibility of sensing events, while the management nodes perform management of both types of nodes during cluster formation. EDFCM is specially proposed for heterogeneous networks to provide the longer lifetime and more reliable transmission service. Unlike the other energy efficient protocols, the process of cluster head selection in EDFCM is based on a method of one-step energy consumption forecast. It uses the average energy consumptions of the two types of cluster heads in previous round for this purpose. The more remaining energy in a node after the operation of next round, higher the chances of node to be selected as a cluster head [3].

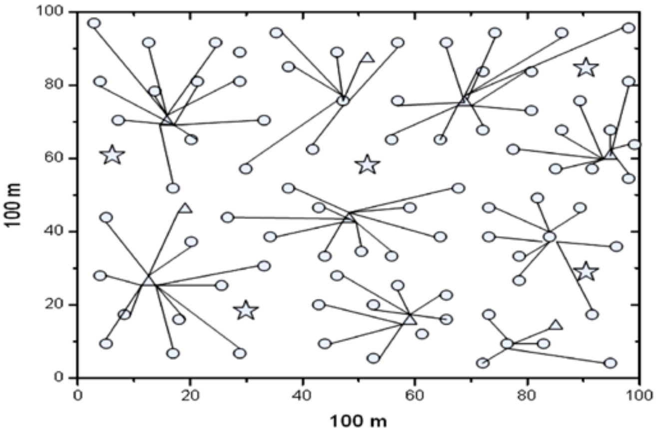

Figure 4: Type_1 and Type_2 nodes are shown by circle and triangle respectively and management nodes by star

D. Base Station Initiated Dynamic Routing Protocol:

S. Verma *et al.* propose a routing protocol that is based on clustering and uses heterogeneity in nodes to increase the network lifetime. In this scheme, some nodes which are stronger than other nodes in terms of power, computational capability and location awareness, work as the cluster heads. They forward information to their parents, towards the base station by aggregating all the information from their clusters members. Following assumptions are considered in this scheme: all nodes are deployed uniformly in the field and CHs will be assumed dead only when their energy is very less. There is no collision between inter cluster and intra cluster communication. Transmission power of the CH is adjusted in such a way that only single hop broadcast is possible. In this algorithm, how far a CH is from the BS, is defined as level. Low level means that CH is near to the BS and if level is high it means CH is away from BS accordingly. Data flow will be always from higher level to lower level. Decision of levels by base station is based on the range of the CH and normal node. Ranges of all the nodes

are enough to ensure the connectivity and coverage. BS sets its level to zero and broadcasts a packet to initiate the scheme. Base station mentions that this packet is only for CHs. Since the CHs have different signal strength from normal nodes, they receive

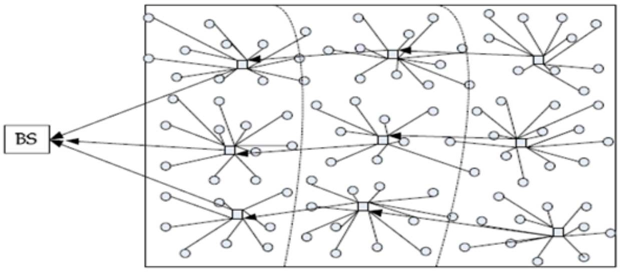

Figure 5: Cluster hierarchy in sensing field

different signal strength from normal nodes, they receive the packet and set their levels accordingly. When the CHs of first level are selected, they broadcast their level. CHs at lower level receive the packet according to the signal strength[2]. They choose their parent from upper level CHs only. This process is repeated again and again until all CHs are connected. CH now broadcast a message that all sensor nodes should join the CH according to the RSS (Radio Signal Strength). Communication between CH and sensing nodes is single hop, while communication between different CH is multiple hops. All CHs sends their position, level and energy consumption to the BS at the end of the round. BS then analyzes the energy consumption of different CH at the same level.

VI. COMPARATIVE STUDY

Table1: Comparisons

	Classification	*Mobility*	*Power usage*	*Scalability*
LCA	Heuristics	CH mobile	Max	Good
WCA	Weighted	CH fixed	Limited	Limited
LEACH	Hierarchical	BS fixed	Max	Good
PEGASIS	Grid	BS fixed	Max	Good

VII. CONCLUSION AND FUTURE SCOPE

In this paper we have examined the current state of proposed clustering protocols, specifically with respect to their power and reliability requirements. In wireless sensor networks, the energy limitations of nodes play a crucial role in designing any protocol for implementation [1]. In addition, Quality of Service metrics such as delay, data loss tolerance, and network lifetime expose reliability issues when designing recovery mechanisms for clustering schemes. These important characteristics are often opposed, as one often has a negative impact on the other. Protocols presented in this paper offer a promising improvement over conventional clustering; however there is still much work to be done. Many energy improvements thus far have focused with minimization of energy associated in the cluster-head selection process. Wireless sensor networks are not always homogeneous, they may be heterogeneous too. This paper surveys research protocols for clustering in heterogeneous wireless sensor networks. Clustering is a good technique to reduce energy consumption and to provide stability in wireless sensor networks. We classified all protocols according to stability and energy efficiency of network. We summarize a number of schemes, stating their strengths and limitations. Finally on the basis of survey work, we conclude that the heterogeneous wireless sensor networks are more suitable for real life applications as compared to the homogeneous counterpart.

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